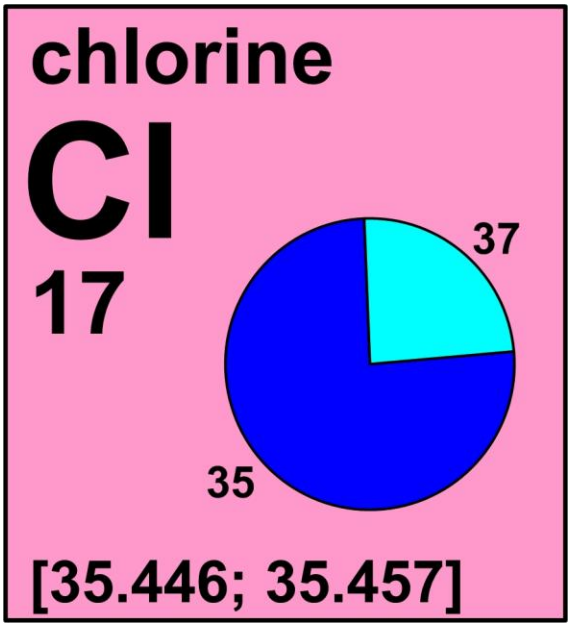
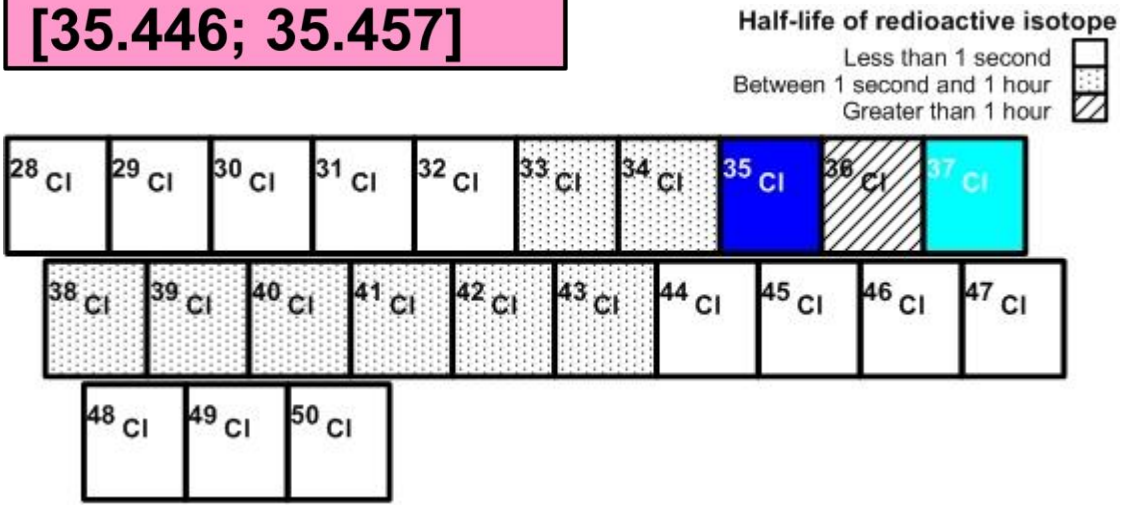
chlorine



Stable isotope	Atomic mass*	Mole fraction
^{35}Cl	34.968 852 68	0.7576
^{37}Cl	36.965 902 59	0.2424

* Atomic mass given in unified atomic mass units, u.



Important applications of stable and/or radioactive isotopes

Isotopes in geochronology

1) Radioactive ^{36}Cl provides a useful chronometer in geology and hydrology. Some radioactive ^{36}Cl is cosmogenic and enters the terrestrial environment in precipitation. Because of its long half-life, gradients in the concentration of cosmogenic ^{36}Cl in aquifers can be used to estimate ages of old meteoric groundwaters (of the order of 10^5 to 10^6 years), after accounting for additional components produced by nuclear reactions in the subsurface. In this way, it is estimated that some aquifers contain groundwater that infiltrated more than one million years ago. This is important information for managers wondering about the sustainability of water supplies.
2) Large amounts of anthropogenic ^{36}Cl were produced by neutron reactions with ^{35}Cl in seawater during oceanic thermonuclear bomb tests, especially in the late 1950s. This ^{36}Cl was deposited with precipitation and entered terrestrial soils and groundwaters, providing a widely distributed transient tracer of meteoric water from that era. The location of "bomb-peak" ^{36}Cl can be used to

estimate infiltration rates and recharge rates for groundwater sustainability studies at decadal time scales.

Isotopes in forensics

1) Chlorine is subject to stable isotope fractionation by physical and chemical processes. Variations in $^{37}Cl/^{35}Cl$ ratios provide evidence for ultrafiltration and crystallization of brines, and indicate sources of Cl-bearing contaminants such as solvents and rocket fuels in the environment.
2) As an example of multiple-isotope forensic application, consider perchlorate (ClO_4^-), which is a widespread groundwater contaminant that can interfere with hormone production in the thyroid gland by displacing iodide. Perchlorate has both natural and anthropogenic sources, so its occurrence in specific locations may be controversial. Both the stable Cl isotope ratio ($^{37}Cl/^{35}Cl$) and the relative abundance of cosmogenic ^{36}Cl ($^{36}Cl/^{35}Cl$) provide useful information about origins of perchlorate in the environment. When combined with stable O isotope ratios ($^{17}O/^{16}O$, $^{18}O/^{16}O$), these data can be used to discriminate sources of perchlorate in areas where this may be important for legal reasons and to guide remedial actions (Figure 1). Analyses of this type indicate that some perchlorate occurrences in US groundwater resulted from a complex sequence of events: (1) formed naturally by photochemical reactions in the stratosphere, (2) deposited and accumulated in the hyperarid Atacama Desert in Chile; (3) incorporated inadvertently with natural nitrate fertilizer mined in the Atacama Desert and exported to the US; and (4) applied to crops and infiltrated with groundwater recharge. Other occurrences can be attributed by the isotopic method to other natural sources or human activities, such as rocket fuel spills or fireworks disposal.

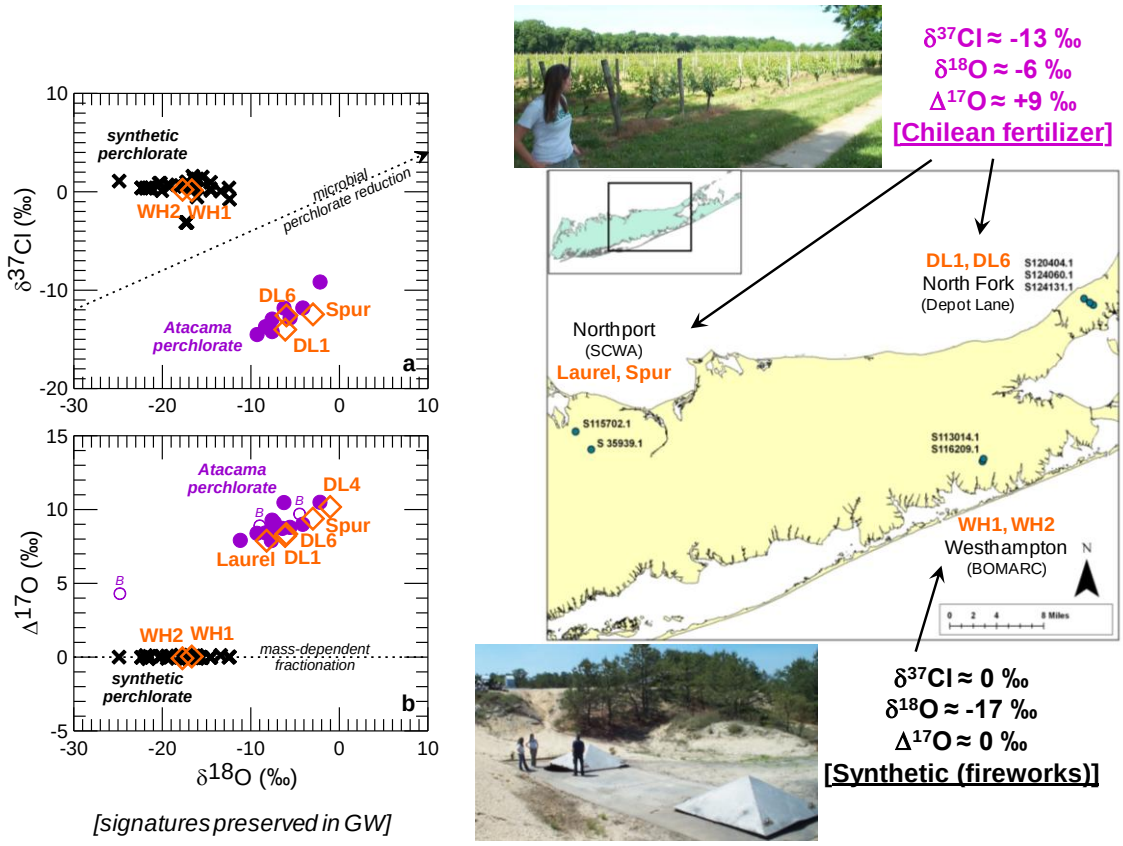


Figure 1**:** Identifying sources of perchlorate contamination in groundwater beneath Long Island, NY. The isotopic composition of perchlorate is related to the progenitor compounds and the processes of formation of the perchlorate molecules. Wells in different parts of Long Island apparently were contaminated by different sources, including fireworks disposal and agriculture. The agriculture source is identified as nitrate fertilizer from Chile, where natural nitrate and perchlorate are mined and processed for export. The agricultural perchlorate contamination is a "legacy" of the past, when Chilean nitrate fertilizers had relatively high perchlorate concentrations and were used more intensively. Nonetheless, it adds to the cost of producing drinking water if it exceeds local recommended levels in the groundwater that enters the wells.